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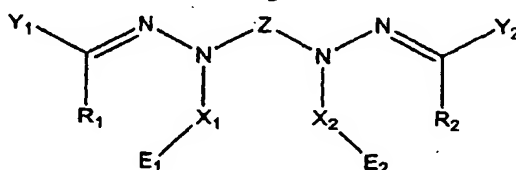
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(54) **Organophotoreceptor with a charge transport material having two epoxidated-hydrazone groups**

(57) The present invention provides organophotoreceptors comprising an electrically conductive substrate and a photoconductive element on the electrically conductive substrate, the photoconductive element comprising:

(a) a charge transport material having the formula



where  $Y_1$  and  $Y_2$  are, each independently, an arylamine group;

$R_1$  and  $R_2$  comprise, each independently, H, an alkyl group, an alkenyl group, a heterocyclic group, or an aromatic group;

$X_1$  and  $X_2$ , each independently, are bridging groups;

$E_1$  and  $E_2$  are, each independently, an epoxy group; and

Z is a linking group comprising an alkyl group, an alkenyl group, a heterocyclic group, or an aromatic group;

and

(b) a charge generating compound.

The charge transport materials can be crosslinked to a polymeric binder, either directly or through a crosslinking agent. Corresponding electrophotographic apparatuses and imaging methods (processes) are described, as are corresponding charge transport materials.

## Description

**[0001]** This invention relates to organophotoreceptors suitable for use in electrophotography and, more specifically, to organophotoreceptors having a charge transport material comprising at least two epoxy groups, each bonded directly or indirectly through a bridging group to a nitrogen atom of a hydrazone group. Each epoxy group may or may not be covalently bonded with a polymeric binder, directly or through a crosslinking compound.

**[0002]** In electrophotography, an organophotoreceptor in the form of a plate, disk, sheet, belt, drum or the like having an electrically insulating photoconductive element on an electrically conductive substrate is imaged by first uniformly electrostatically charging the surface of the photoconductive layer, and then exposing the charged surface to a pattern of light. The light exposure selectively dissipates the charge in the illuminated areas where light strikes the surface, thereby forming a pattern of charged and uncharged areas, referred to as a latent image. A liquid or dry toner is then provided in the vicinity of the latent image, and toner droplets or particles deposit in the vicinity of either the charged or uncharged areas to create a toned image on the surface of the photoconductive layer. The resulting toned image can be transferred to a suitable ultimate or intermediate receiving surface, such as paper, or the photoconductive layer can operate as an ultimate receptor for the image. The imaging process can be repeated many times to complete a single image, for example, by overlaying images of distinct color components or effect shadow images, such as overlaying images of distinct colors to form a full color final image, and/or to reproduce additional images.

**[0003]** Both single layer and multilayer photoconductive elements have been used. In single layer embodiments, a charge transport material and charge generating material are combined with a polymeric binder and then deposited on the electrically conductive substrate. In multilayer embodiments, the charge transport material and charge generating material are present in the element in separate layers, each of which can optionally be combined with a polymeric binder, deposited on the electrically conductive substrate. Two arrangements are possible for a two-layer photoconductive element. In one two-layer arrangement (the "dual layer" arrangement), the charge-generating layer is deposited on the electrically conductive substrate and the charge transport layer is deposited on top of the charge generating layer. In an alternate two-layer arrangement (the "inverted dual layer" arrangement), the order of the charge transport layer and charge generating layer is reversed.

**[0004]** In both the single and multilayer photoconductive elements, the purpose of the charge generating material is to generate charge carriers (i.e., holes and/or electrons) upon exposure to light. The purpose of the charge transport material is to accept at least one type of these charge carriers and transport them through the charge transport layer in order to facilitate discharge of a surface charge on the photoconductive element. The charge transport material can be a charge transport compound, an electron transport compound, or a combination of both. When a charge transport compound is used, the charge transport compound accepts the hole carriers and transports them through the layer with the charge transport compound. When an electron transport compound is used, the electron transport compound accepts the electron carriers and transports them through the layer with the electron transport compound.

**[0005]** Organophotoreceptors may be used for both dry and liquid electrophotography. There are many differences between dry and liquid electrophotography. In particular, a dry toner is used in dry electrophotography, whereas a liquid toner is used in liquid electrophotography. A potential advantage of liquid electrophotography is that it can provide a higher resolution and thus sharper images than dry electrophotography because liquid toner particles can be much smaller than dry toner particles. As a result of their smaller size, liquid toners are able to provide images of higher optical density than dry toners.

**[0006]** In both dry and liquid electrophotography, the charge transport material used for the organophotoreceptor should be compatible with the polymeric binder in the photoconductive element. The desirability of selecting a compatible polymer binder places a constraint on choosing a suitable polymeric binder for a particular charge transport material. If the charge transport material is not compatible with the polymeric binder, the charge transport material may phase-separate or crystallize in the polymeric binder matrix, or will diffuse onto the surface of the layer containing the charge transport material. If such incompatibility occurs, the organophotoreceptor may cease to transport charges.

**[0007]** Furthermore, liquid electrophotography faces an additional complication. In particular, the organophotoreceptor for liquid electrophotography is in contact with the liquid carrier of a liquid toner as the liquid evaporates and/or is transferred to a receiving surface. As a result, the charge transport material in the photoconductive element may be removed through extraction by the liquid carrier. Over a long period of operation, the amount of the charge transport material removed by extraction may be significant and, therefore, detrimental to the performance of the organophotoreceptor.

**[0008]** Although many charge transport materials are known, there is the need for other charge transport materials to meet the various requirements of particular electrophotographic applications.

**[0009]** To produce high quality images, particularly after multiple cycles, it is desirable for the charge transport materials to form a homogeneous solution with the polymeric binder and remain approximately homogeneously distributed through the organophotoreceptor material during the cycling of the material. In addition, it is desirable to increase the amount of charge that the charge transport material can accept (indicated by a parameter known as the acceptance

voltage or " $V_{acc}$ "), and to reduce retention of that charge upon discharge (indicated by a parameter known as the discharge voltage or " $V_{dis.}$ ").

**[0010]** An aim of the present invention is to provide organophotoreceptors, electrophotographic imaging apparatus, electrophotographic imaging processes, and charge transport materials, preferably generally featuring (a) good, and/or beneficial, and/or useful propert(y)ies, or combinations of such properties, and preferably addressing at least one or some of the problems in the art.

**[0011]** There are many charge transport materials available for electrophotography, including, for example, pyrazoline derivatives, fluorene derivatives, oxadiazole derivatives, stilbene derivatives, hydrazone derivatives, carbazole hydrazone derivatives, triaryl amines, polyvinyl carbazole, polyvinyl pyrene, and polyacenaphthylene. However, at least some of the available charge transport materials may suffer some disadvantages and thus there is always the need for charge transport materials to meet the various requirements of electrophotography applications. This represents a further preferred aim of the present invention.

**[0012]** A preferred aim of the present invention is to provide organophotoreceptors having good electrostatic properties.

**[0013]** Moreover, a further preferred aim of the present invention is to provide charge transport materials for organophotoreceptors featuring good mechanical and/or chemical properties, and/or a combination of good mechanical and electrostatic properties.

**[0014]** Suitably, a further aim of embodiments of the present invention is to provide organophotoreceptors and electrophotographic imaging apparatus which can be used to provide high quality of images, even after repeated cycling, electrophotographic apparatus employing the organophotoreceptors and electrophotographic imaging methods using the organophotoreceptors/charge transport materials.

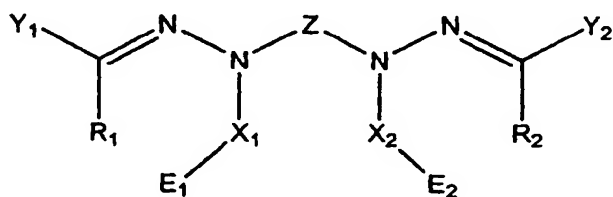
**[0015]** Other aims and/or advantages of the invention will be set forth in part in the description which follows and, in part, will be apparent or obvious from the description, or may be apparent from, or learned by, practice of the invention.

**[0016]** According to the present invention there is provided an organophotoreceptor, an electrophotographic imaging apparatus, an electrophotographic imaging process, a charge transport material, and a polymeric charge transport material, as set forth in the appended claims. Preferred features of the invention will be apparent from the dependent claims, and the description which follows.

**[0017]** Accordingly, this invention seeks to provide organophotoreceptors having good electrostatic properties such as high  $V_{acc}$  and low  $V_{dis}$ . This invention also seeks to provide charge transport materials having a high compatibility with the polymeric binder, reduced phase separation, and reduced extraction by liquid carriers.

**[0018]** In a first aspect of the present invention there is provided an organophotoreceptor comprising an electrically conductive substrate and a photoconductive element on the electrically conductive substrate, the photoconductive element comprising:

(a) a charge transport material having the formula



(1)

where Y<sub>1</sub> and Y<sub>2</sub> are, each independently, an arylamine group;

$R_1$  and  $R_2$  comprise, each independently, H, an alkyl group, an alkenyl group, a heterocyclic group, or an aromatic group;

X<sub>1</sub> and X<sub>2</sub>, each independently, are bridging groups, such as groups having the formula -(CH<sub>2</sub>)<sub>m</sub>-, branched or linear, where m is an integer between 0 and 20, inclusive, and one or more of the methylene groups is optionally replaced by O, S, C=O, O=S=O, a heterocyclic group, an aromatic group, urethane, urea, an ester group, an NR<sub>3</sub> group, a CHR<sub>4</sub> group, or a CR<sub>5</sub>R<sub>6</sub> group where R<sub>3</sub>, R<sub>4</sub>, R<sub>5</sub>, and R<sub>6</sub> comprise, each independently, H, hydroxyl group, thiol group, an alkyl group, an alkenyl group, a heterocyclic group, or an aromatic group;

E<sub>1</sub> and E<sub>2</sub> are, each independently, an epoxy group; and

Z is a linking group comprising an alkyl group, an alkenyl group, a heterocyclic group, or an aromatic group;

and

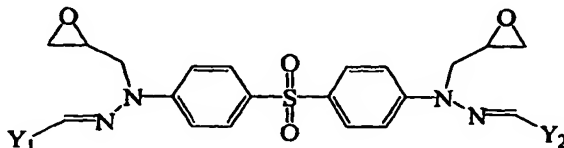
(b) a charge generating compound.

[0019] Preferably, Z comprises an aromatic group.

[0020] Preferably,  $Y_1$  and  $Y_2$  are, each independently, a carbazolyl group, an (N,N-disubstituted)arylamine group, or a julolidinyl group.

[0021] Preferably,  $E_1$  and  $E_2$  are, each independently, an oxiranyl ring.

[0022] Preferably, the charge transport material is selected from the group of compounds represented by the following formula:



where  $Y_1$  and  $Y_2$  are, each independently, an arylamine group.

[0023] Preferably, the photoconductive element further comprises a second charge transport material.

[0024] Preferably, the second charge transport material comprises an electron transport compound.

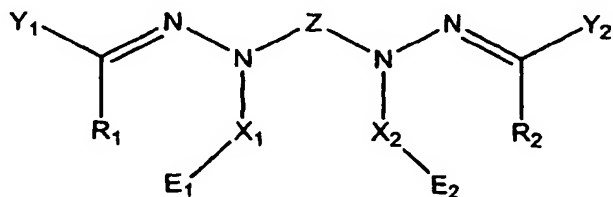
[0025] Preferably, the photoconductive element further comprises a binder.

[0026] The organophotoreceptor may be provided, for example, in the form of a plate, a flexible belt, a flexible disk, a sheet, a rigid drum, or a sheet around a rigid or compliant drum. In one embodiment, the organophotoreceptor includes: (a) a photoconductive element comprising the charge transport material, the charge generating compound, a second charge transport material, and a polymeric binder; and (b) the electrically conductive substrate.

[0027] In a second aspect of the present invention there is provided an electrophotographic imaging apparatus that comprises (a) a light imaging component; and (b) the organophotoreceptor described herein oriented to receive light from the light imaging component. The apparatus can further comprise a liquid toner dispenser. The method of electrophotographic imaging with photoreceptors containing the above noted charge transport materials is also described.

[0028] In a third aspect of the present invention there is provided an electrophotographic imaging process that includes (a) applying an electrical charge to a surface of the organophotoreceptor described herein; (b) imagewise exposing the surface of the organophotoreceptor to radiation to dissipate charge in selected areas and thereby form a pattern of at least relatively charged and uncharged areas on the surface; (c) contacting the surface with a toner, such as a liquid toner that includes a dispersion of colorant particles in an organic liquid, to create a toned image; and (d) transferring the toned image to a substrate.

[0029] In a fourth aspect of the present invention there is provided a charge transport material having the general formula above, i.e. the formula



(1)

where  $Y_1$  and  $Y_2$  are, each independently, an arylamine group;

$R_1$  and  $R_2$  comprise, each independently, H, an alkyl group, an alkenyl group, a heterocyclic group, or an aromatic group;

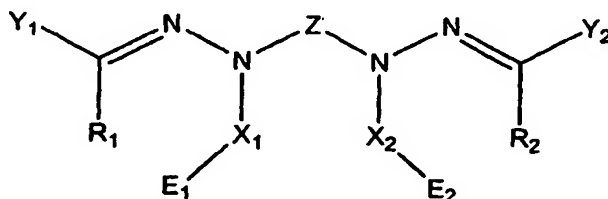
$X_1$  and  $X_2$ , each independently, are bridging groups, such as groups having the formula  $-(CH_2)_m-$ , branched or linear, where m is an integer between 0 and 20, inclusive, and one or more of the methylene groups is optionally replaced by O, S, C=O, O=S=O, a heterocyclic group, an aromatic group, urethane, urea, an ester group, an  $NR_3$

group, a  $\text{CHR}_4$  group, or a  $\text{CR}_5\text{R}_6$  group where  $\text{R}_3$ ,  $\text{R}_4$ ,  $\text{R}_5$ , and  $\text{R}_6$  comprise, each independently, H, hydroxyl group, thiol group, an alkyl group, an alkenyl group, a heterocyclic group, or an aromatic group;

$\text{E}_1$  and  $\text{E}_2$  are, each independently, an epoxy group; and

$\text{Z}$  is a linking group comprising an alkyl group, an alkenyl group, a heterocyclic group, or an aromatic group.

**[0030]** In a fifth aspect of the present invention there is provided a polymeric charge transport material prepared by the reaction of a functional group in a polymeric binder with at least an epoxy group in a compound having the formula



where  $\text{Y}_1$  and  $\text{Y}_2$  are, each independently, an arylamine group;

$\text{R}_1$  and  $\text{R}_2$  comprise, each independently, H, an alkyl group, an alkenyl group, a heterocyclic group, or an aromatic group;

$\text{X}_1$  and  $\text{X}_2$ , each independently, are bridging groups, such as groups having the formula  $-(\text{CH}_2)_m-$ , branched or linear, where  $m$  is an integer between 0 and 20, inclusive, and one or more of the methylene groups is optionally replaced by O, S, C=O, O=S=O, a heterocyclic group, an aromatic group, urethane, urea, an ester group, an  $\text{NR}_3$  group, a  $\text{CHR}_4$  group, or a  $\text{CR}_5\text{R}_6$  group where  $\text{R}_3$ ,  $\text{R}_4$ ,  $\text{R}_5$ , and  $\text{R}_6$  comprise, each independently, H, hydroxyl group, thiol group, an alkyl group, an alkenyl group, a heterocyclic group, or an aromatic group;

$\text{E}_1$  and  $\text{E}_2$  are, each independently, an epoxy group; and

$\text{Z}$  is a linking group comprising an alkyl group, an alkenyl group, a heterocyclic group, or an aromatic group.

**[0031]** In a sixth aspect of the present invention there is provided an organophotoreceptor comprising an electrically conductive substrate and a photoconductive element on the electrically conductive substrate, the photoconductive element comprising:

- (a) the polymeric charge transport material described above; and
- (b) a charge generating compound.

**[0032]** The invention provides suitable charge transport materials for organophotoreceptors featuring a combination of good mechanical and electrostatic properties. These photoreceptors can be used successfully with liquid toners to produce high quality images. The high quality of the imaging system can be maintained after repeated cycling. The invention provides organophotoreceptors having good electrostatic properties such as high  $V_{\text{acc}}$  and low  $V_{\text{dis}}$ . The invention also provides charge transport materials having a high compatibility with the polymeric binder, reduced phase separation, and reduced extraction by liquid carriers.

**[0033]** Other features and advantages of the invention will be apparent from the following description of the particular embodiments thereof, and from the claims.

**[0034]** Features and embodiments described herein of the first, second, third, fourth, fifth and sixth aspects of the present invention, respectively, may be regarded as preferred features and embodiments of other aspects of the present invention.

**[0035]** An organophotoreceptor, as described herein, has an electrically conductive substrate and a photoconductive element comprising a charge generating compound and a charge transport material having two epoxy groups, each bonded directly or indirectly to an N atom of a hydrazone group to form a compound with two linked epoxidated-hydrazone groups. These charge transport materials have desirable properties as evidenced by their performance in organophotoreceptors for electrophotography. In particular, the charge transport materials of this invention have high charge carrier mobilities and good compatibility with various binder materials, and possess excellent electrophotographic properties. The organophotoreceptors according to this invention generally have a high photosensitivity, a low residual potential, and a high stability with respect to cycle testing, crystallization, and organophotoreceptor bending and stretching. The organophotoreceptors are particularly useful in laser printers and the like as well as fax machines, photocopiers, scanners and other electronic devices based on electrophotography. The use of these charge transport materials is described in more detail below in the context of laser printer use, although their application in other devices operating by electrophotography can be generalized from the discussion below.

**[0036]** As noted above, to produce high quality images, particularly after multiple cycles, it is desirable for the charge transport materials to form a homogeneous solution with the polymeric binder and remain approximately homogene-

ously distributed through the organophotoreceptor material during the cycling of the material. In addition, it is desirable to increase the amount of charge that the charge transport material can accept (indicated by a parameter known as the acceptance voltage or " $V_{acc}$ "), and to reduce retention of that charge upon discharge (indicated by a parameter known as the discharge voltage or " $V_{dis}$ ").

**[0037]** The charge transport materials can be classified as a charge transport compound or an electron transport compound. There are many charge transport compounds and electron transport compounds known in the art for electrophotography. Non-limiting examples of charge transport compounds include, for example, pyrazoline derivatives, fluorene derivatives, oxadiazole derivatives, stilbene derivatives, enamine derivatives, enamine stilbene derivatives, hydrazone derivatives, carbazole hydrazone derivatives, (N,N-disubstituted)arylamines such as triaryl amines, polyvinyl carbazole, polyvinyl pyrene, polyacenaphthylene, or multi-hydrazone compounds comprising at least two hydrazone groups and at least two groups selected from the group consisting of (N,N-disubstituted)arylamines such as triphenylamine and heterocycles such as carbazole, julolidine, phenothiazine, phenazine, phenoxazine, phenoxathiin, thiazole, oxazole, isoxazole, dibenzo(1,4)dioxin, thianthrene, imidazole, benzothiazole, benzotriazole, benzoxazole, benzimidazole, quinoline, isoquinoline, quinoxaline, indole, indazole, pyrrole, purine, pyridine, pyridazine, pyrimidine, pyrazine, triazole, oxadiazole, tetrazole, thiadiazole, benzisoxazole, benzisothiazole, dibenzofuran, dibenzothiophene, thiophene, thianaphthene, quinazoline, or cinnoline.

**[0038]** Non-limiting examples of electron transport compounds include, for example, bromoaniline, tetracyanoethylene, tetracyanoquinodimethane, 2,4,7-trinitro-9-fluorenone, 2,4,5,7-tetranitro-9-fluorenone, 2,4,5,7-tetranitroxanthone, 2,4,8-trinitrothioxanthone, 2,6,8-trinitro-indeno[1,2-b]thiophene-4-one, and 1,3,7-trinitrodibenzo thiophene-5,5-dioxide, (2,3-diphenyl-1-indenylidene)malononitrile, 4H-thiopyran-1,1-dioxide and its derivatives such as 4-dicyanomethylene-2,6-diphenyl-4H-thiopyran-1,1-dioxide, 4-dicyanomethylene-2,6-di-m-tolyl-4H-thiopyran-1,1-dioxide, and unsymmetrically substituted 2,6-diaryl-4H-thiopyran-1,1-dioxide such as 4H-1,1-dioxo-2-(p-isopropylphenyl)-6-phenyl-4-(dicyanomethylidene)thiopyran and 4H-1,1-dioxo-2-(p-isopropylphenyl)-6-(2-thienyl)-4-(dicyanomethylidene)thiopyran, derivatives of phospho-2,5-cyclohexadiene, alkoxycarbonyl-9-fluorenylidene)malononitrile derivatives such as (4-n-butoxycarbonyl-9-fluorenylidene)malononitrile, (4-phenethoxycarbonyl-9-fluorenylidene)malononitrile, (4-carbitoxy-9-fluorenylidene)malononitrile, and diethyl(4-n-butoxycarbonyl-2,7-dinitro-9-fluorenylidene)-malonate, anthraquinodimethane derivatives such as 11,11,12,12-tetracyano-2-alkylanthraquinodimethane and 11,11-dicyano-12,12-bis(ethoxycarbonyl)anthraquinodimethane, anthrone derivatives such as 1-chloro-10-[bis(ethoxycarbonyl)methylene]anthrone, 1,8-dichloro-10-[bis(ethoxy carbonyl) methylene]anthrone, 1,8-dihydroxy-10-[bis(ethoxycarbonyl)methylene]anthrone, and 1-cyano-10-[bis(ethoxycarbonyl)methylene]anthrone, 7-nitro-2-aza-9-fluorenylidene-malononitrile, diphenoquinone derivatives, benzoquinone derivatives, napthoquinone derivatives, quinine derivatives, tetracyanoethylenecyanoethylene, 2,4,8-trinitro thioxanthone, dinitrobenzene derivatives, dinitroanthracene derivatives, dinitroacridine derivatives, nitroanthraquinone derivatives, dinitroanthraquinone derivatives, succinic anhydride, maleic anhydride, dibromo maleic anhydride, pyrene derivatives, carbazole derivatives, hydrazone derivatives, N,N-dialkylaniline derivatives, diphenylamine derivatives, triphenylamine derivatives, triphenylmethane derivatives, tetracyano quinoedimethane, 2,4,5,7-tetranitro-9-fluorenone, 2,4,7-trinitro-9-dicyanomethylene fluorenone, 2,4,5,7-tetranitroxanthone derivatives, and 2,4,8-trinitrothioxanthone derivatives. In some embodiments of interest, the electron transport compound comprises an (alkoxycarbonyl-9-fluorenylidene)malononitrile derivative, such as (4-n-butoxycarbonyl-9-fluorenylidene)malononitrile.

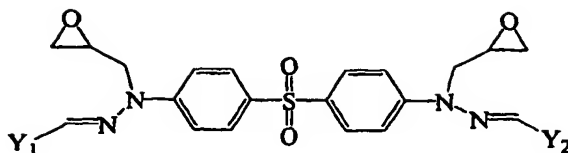
**[0039]** Although there are many charge transport materials available, there is, as noted above, a need for other charge transport materials to meet the various requirements of particular electrophotography applications.

**[0040]** In electrophotography applications, a charge-generating compound within an organophotoreceptor absorbs light to form electron-hole pairs. These electrons and holes can be transported over an appropriate time frame under a large electric field to discharge locally a surface charge that is generating the field. The discharge of the field at a particular location results in a surface charge pattern that essentially matches the pattern drawn with the light. This charge pattern then can be used to guide toner deposition. The charge transport materials described herein are especially effective at transporting charge, and in particular holes from the electron-hole pairs formed by the charge generating compound. In some embodiments, a specific electron transport compound or charge transport compound can also be used along with the charge transport material of this invention.

**[0041]** The layer or layers of materials containing the charge generating compound and the charge transport materials are within an organophotoreceptor. To print a two dimensional image using the organophotoreceptor, the organophotoreceptor has a two dimensional surface for forming at least a portion of the image. The imaging process then continues by cycling the organophotoreceptor to complete the formation of the entire image and/or for the processing of subsequent images.

**[0042]** The organophotoreceptor may be provided in the form of a plate, a flexible belt, a disk, a rigid drum, a sheet around a rigid or compliant drum, or the like. The charge transport material can be in the same layer as the charge generating compound and/or in a different layer from the charge generating compound. Additional layers can be used also, as described further below.





where  $Y_1$  and  $Y_2$  are, each independently, an arylamine group.

**[0051]** Preferably, the photoconductive element of the organophotoreceptor further comprises a second charge transport material.

**[0052]** Preferably, the second charge transport material comprises an electron transport compound.

**[0053]** Preferably, the photoconductive element of the organophotoreceptor further comprises a binder.

**[0054]** In some embodiments,  $Z$  comprises an aromatic group. In further embodiments  $R_1$  and  $R_2$  are both H.

**[0055]** In some embodiments,  $X_1$  and  $X_2$  each independently, are bridging groups, such as groups having the formula  $-(CH_2)_m-$ , branched or linear, where  $m$  is an integer between 0 and 12, inclusive, especially between 0 and 6, inclusive, notably 1, and one or more of the methylene groups is optionally replaced by O, S, C=O, O=S=O, a heterocyclic group, an aromatic group, urethane, urea, an ester group, an  $NR_3$  group, a  $CHR_4$  group, or a  $CR_5R_6$  group where  $R_3$ ,  $R_4$ ,  $R_5$ , and  $R_6$  comprise, each independently, H, hydroxyl group, thiol group, an alkyl group, an alkenyl group, a heterocyclic group, or an aromatic group.

**[0056]** The aromatic group can be any conjugated system containing  $4n + 2$   $\pi$ -electrons. There are many criteria available for determining aromaticity. A widely employed criterion for the quantitative assessment of aromaticity is the resonance energy. In general, the resonance energy of the aromatic group is greater than 10 KJ/mol. Aromatic groups may be classified as an aromatic heterocyclic group which contains at least a heteroatom in the  $4n + 2$   $\pi$ -electron ring, or as an aryl group which does not contain a heteroatom in the  $4n + 2$   $\pi$ -electron ring. Nonetheless, either the aromatic heterocyclic or the aryl group may have at least one heteroatom in a substituent attached to the  $4n + 2$   $\pi$ -electron ring. Furthermore, either the aromatic heterocyclic or the aryl group may comprise a monocyclic or polycyclic (such as bicyclic, tricyclic, etc.) aromatic ring.

**[0057]** Non-limiting examples of the aromatic heterocyclic group are furanyl, thiophenyl, pyrrolyl, indolyl, carbazoyl, benzofuranyl, benzothiophenyl, dibenzofuranyl, dibenzothiophenyl, pyridinyl, pyridazinyl, pyrimidinyl, pyrazinyl, triazinyl, tetrazinyl, petazinyl, quinolinyl, isoquinolinyl, cinnolinyl, phthalazinyl, quinazolinyl, quinoxaliny, naphthyridinyl, pteridinyl, acridinyl, phenanthridinyl, phenanthrolinyl, anthyridinyl, purinyl, pteridinyl, alloxazinyl, phenazinyl, phenothiazinyl, phenoxazinyl, phenoxathiinyl, dibenzo(1,4)dioxinyl, thianthrenyl, and a combination thereof. The aromatic heterocyclic group may also include any combination of the above aromatic heterocyclic groups bonded together either by a bond (as in bicarbazoyl) or by a linking group (as in 1,6-di(10H-10-phenothiazinyl)hexane). The linking group may include an aliphatic group, an aromatic group, a heterocyclic group, or a combination thereof. Furthermore, either an aliphatic group or an aromatic group within a linking group may comprise at least one heteroatom such as O, S, and N.

**[0058]** Non-limiting examples of the aryl group are phenyl, naphthyl, benzyl, or tolanyl group, sexiphenylene, phenanthrenyl, anthracenyl, coronenyl, and tolanylphenyl. The aryl group may also include any combination of the above aryl groups bonded together either by a bond (as in biphenyl group) or by a linking group (as in stilbenyl, diphenyl sulfone, an arylamine group). The linking group may include an aliphatic group, an aromatic group, a heterocyclic group, or a combination thereof. Furthermore, either an aliphatic group or an aromatic group within a linking group may comprise at least one heteroatom such as O, S, and N.

**[0059]** An arylamine group includes an (N,N-disubstituted)arylamine group (e.g., triarylamine group, alkyldiarylamine group, and dialkylarylamine group), julolidinyl group, and a carbazoyl group.

**[0060]** Substitution is liberally allowed on the chemical groups to affect various physical effects on the properties of the compounds, such as mobility, sensitivity, solubility, compatibility, stability, and the like, as is known generally in the art. In the description of chemical substituents, there are certain practices common to the art that are reflected in the use of language. The term group indicates that the generically recited chemical entity (e.g., alkyl group, alkenyl group, aromatic group, epoxy group, arylamine group, etc.) may have any substituent thereon which is consistent with the bond structure of that group. For example, where the term 'alkyl group' is used, that term would not only include unsubstituted linear, branched and cyclic alkyls, such as methyl, ethyl, isopropyl, tert-butyl, cyclohexyl, dodecyl and the like, but also substituents having heteroatom such as 3-ethoxypropyl, 4-(N-ethylamino)butyl, 3-hydroxypentyl, 2-thiolhexyl, 1,2,3-tribromopropyl, and the like. However, as is consistent with such nomenclature, no substitution would be included within the term that would alter the fundamental bond structure of the underlying group. For example, where a phenyl group is recited, substitution such as 1-aminophenyl, 2,4-dihydroxyphenyl, 1,3,5-trithiophenyl, 1,3,5-trimethoxyphenyl and the like would be acceptable within the terminology, while substitution of 1,1,2,2,3,3-hexamethyl-



phenyl would not be acceptable as that substitution would require the ring bond structure of the phenyl group to be altered to a non-aromatic form because of the substitution. When referring to an epoxy group, the substituent cited will include any substitution that does not destroy the 3-membered ring structure of the epoxy group. Where the term moiety is used, such as alkyl moiety or phenyl moiety, that terminology indicates that the chemical moiety is not substituted. When referring to an alkyl moiety, the term represents only an unsubstituted alkyl hydrocarbon group, whether branched, straight chain, or cyclic.

**[0061]** In general, and except where stated otherwise herein, the following apply. Preferred alkyl groups are C<sub>1-16</sub> alkyl, especially C<sub>1-12</sub> alkyl, more especially C<sub>1-8</sub> alkyl, even more especially C<sub>1-4</sub> alkyl, suitably substituted or unsubstituted, suitably linear, branched or cyclic.

#### Organophotoreceptors

**[0062]** The organophotoreceptor may be, for example, in the form of a plate, a sheet, a flexible belt, a disk, a rigid drum, or a sheet around a rigid or compliant drum, with flexible belts and rigid drums generally being used in commercial embodiments. The organophotoreceptor may comprise, for example, an electrically conductive substrate and on the electrically conductive substrate a photoconductive element in the form of one or more layers. The photoconductive element can comprise both a charge transport material and a charge generating compound in a polymeric binder, which may or may not be in the same layer, as well as a second charge transport material such as a charge transport compound or an electron transport compound in some embodiments. For example, the charge transport material and the charge generating compound can be in a single layer. In other embodiments, however, the photoconductive element comprises a bilayer construction featuring a charge generating layer and a separate charge transport layer. The charge generating layer may be located intermediate between the electrically conductive substrate and the charge transport layer. Alternatively, the photoconductive element may have a structure in which the charge transport layer is intermediate between the electrically conductive substrate and the charge generating layer.

**[0063]** The electrically conductive substrate may be flexible, for example in the form of a flexible web or a belt, or inflexible, for example in the form of a drum. A drum can have a hollow cylindrical structure that provides for attachment of the drum to a drive that rotates the drum during the imaging process. Typically, a flexible electrically conductive substrate comprises an electrically insulating substrate and a thin layer of electrically conductive material onto which the photoconductive material is applied.

**[0064]** The electrically insulating substrate may be paper or a film forming polymer such as polyester (e.g., polyethylene terephthalate or polyethylene naphthalate), polyimide, polysulfone, polypropylene, nylon, polyester, polycarbonate, polyvinyl resin, polyvinyl fluoride, polystyrene and the like. Specific examples of polymers for supporting substrates included, for example, polyethersulfone (Stabar™ S-100, available from ICI), polyvinyl fluoride (Tedlar®, available from E.I. DuPont de Nemours & Company), polybisphenol-A polycarbonate (Makrofol™, available from Mobay Chemical Company) and amorphous polyethylene terephthalate (Melinar™, available from ICI Americas, Inc.). The electrically conductive materials may be graphite, dispersed carbon black, iodine, conductive polymers such as polypyrroles and Calgon® conductive polymer 261 (commercially available from Calgon Corporation, Inc., Pittsburgh, Pa.), metals such as aluminum, titanium, chromium, brass, gold, copper, palladium, nickel, or stainless steel, or metal oxide such as tin oxide or indium oxide. In embodiments of particular interest, the electrically conductive material is aluminum. Generally, the photoconductor substrate has a thickness adequate to provide the required mechanical stability. For example, flexible web substrates generally have a thickness from about 0.01 to about 1 mm, while drum substrates generally have a thickness from about 0.5 mm to about 2 mm.

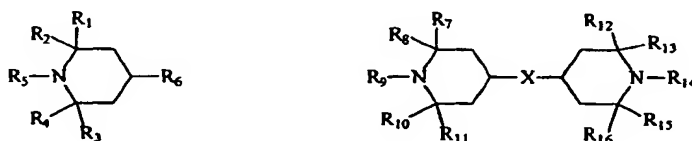
**[0065]** The charge generating compound is a material that is capable of absorbing light to generate charge carriers, such as a dye or pigment. Non-limiting examples of suitable charge generating compounds include, for example, metal-free phthalocyanines (e.g., ELA 8034 metal-free phthalocyanine available from H.W. Sands, Inc. or Sanyo Color Works, Ltd., CGM-X01), metal phthalocyanines such as titanium phthalocyanine, copper phthalocyanine, oxytitanium phthalocyanine (also referred to as titanyl oxyphthalocyanine, and including any crystalline phase or mixtures of crystalline phases that can act as a charge generating compound), hydroxygallium phthalocyanine, squarylium dyes and pigments, hydroxy-substituted squarylium pigments, perylimides, polynuclear quinones available from Allied Chemical Corporation under the trade name Indofast® Double Scarlet, Indofast® Violet Lake B, Indofast® Brilliant Scarlet and Indofast® Orange, quinacridones available from DuPont under the trade name Monastral™ Red, Monastral™ Violet and Monastral™ Red Y, naphthalene 1,4,5,8-tetracarboxylic acid derived pigments including the perinones, tetrabenzoporphyrins and tetranaphthaloporphyrins, indigo- and thioindigo dyes, benzothioxanthene-derivatives, perylene 3,4,9,10-tetracarboxylic acid derived pigments, polyazo-pigments including bisazo-, trisazo- and tetrakisazo-pigments, polymethine dyes, dyes containing quinazoline groups, tertiary amines, amorphous selenium, selenium alloys such as selenium-tellurium, selenium-tellurium-arsenic and selenium-arsenic, cadmium sulphoselenide, cadmium selenide, cadmium sulphide, and mixtures thereof. For some embodiments, the charge generating compound comprises oxytitanium phthalocyanine (e.g., any phase thereof), hydroxygallium phthalocyanine or a combination thereof.

**[0066]** The photoconductive layer of this invention may optionally contain a second charge transport material which may be a charge transport compound, an electron transport compound, or a combination of both. Generally, any charge transport compound or electron transport compound known in the art can be used as the second charge transport material.

**[0067]** An electron transport compound and a UV light stabilizer can have a synergistic relationship for providing desired electron flow within the photoconductor. The presence of the UV light stabilizers alters the electron transport properties of the electron transport compounds to improve the electron transporting properties of the composite. UV light stabilizers can be ultraviolet light absorbers or ultraviolet light inhibitors that trap free radicals.

**[0068]** UV light absorbers can absorb ultraviolet radiation and dissipate it as heat. UV light inhibitors are thought to trap free radicals generated by the ultraviolet light and after trapping of the free radicals, subsequently to regenerate active stabilizer moieties with energy dissipation. In view of the synergistic relationship of the UV stabilizers with electron transport compounds, the particular advantages of the UV stabilizers may not be their UV stabilizing abilities, although the UV stabilizing ability may be further advantageous in reducing degradation of the organophotoreceptor over time. The improved synergistic performance of organophotoreceptors with layers comprising both an electron transport compound and a UV stabilizer are described further in copending U.S. Patent Application Serial Number 10/425,333 filed on April 28, 2003 to Zhu, entitled "Organophotoreceptor With A Light Stabilizer," published as US 2003/0228534 A1, incorporated herein by reference.

**[0069]** Non-limiting examples of suitable light stabilizer include, for example, hindered trialkylamines such as Tinuvin 144 and Tinuvin 292 (from Ciba Specialty Chemicals, Terrytown, NY), hindered alkoxydialkylamines such as Tinuvin 123 (from Ciba Specialty Chemicals), benzotriazoles such as Tinuvin 328, Tinuvin 900 and Tinuvin 928 (from Ciba Specialty Chemicals), benzophenones such as Sanduvor 3041 (from Clariant Corp., Charlotte, N.C.), nickel compounds such as Arbestab (from Robinson Brothers Ltd, West Midlands, Great Britain), salicylates, cyanocinnamates, benzylidene malonates, benzoates, oxanilides such as Sanduvor VSU (from Clariant Corp., Charlotte, N.C.), triazines such as Cyagard UV-1164 (from Cytec Industries Inc., N.J.), polymeric sterically hindered amines such as Luchem (from Atochem North America, Buffalo, NY). In some embodiments, the light stabilizer is selected from the group consisting of hindered trialkylamines having the following formula:



where  $R_1, R_2, R_3, R_4, R_6, R_7, R_8, R_{10}, R_{11}, R_{12}, R_{13}, R_{15}$  and  $R_{16}$  are, each independently, hydrogen, alkyl group, or ester, or ether group; and  $R_5, R_9$ , and  $R_{14}$  are, each independently, alkyl group; and X is a linking group selected from the group consisting of  $-O-CO-(CH_2)_m-CO-O-$  where m is between 2 to 20.

**[0070]** Optionally, the photoconductive layer may comprise a crosslinking agent linking the charge transport material and the binder. As is generally true for crosslinking agents in various contexts, the crosslinking agent comprises a plurality of functional groups or at least one functional group with the ability to exhibit multiple functionality. Specifically, a suitable crosslinking agent generally comprises at least one functional group that reacts with an epoxy group and at least one functional group that reacts with a functional group of the polymeric binder. Non-limiting examples of suitable functional groups for reacting with the epoxy group include hydroxyl, thiol, an amino group, carboxyl group, or a combination thereof. In some embodiments, the functional group of the crosslinking agent for reacting with the polymeric binder does not react significantly with the epoxy group. In general, a person of ordinary skill in the art can select the appropriate functional group of the crosslinking agent to react with the polymeric binder, or similarly, a person of ordinary skill in the art can select appropriate functional groups of the polymeric binder to react with the functional group of the crosslinking agent. Suitable functional groups of the crosslinking agent that do not react significantly with the epoxy group, at least under selected conditions, include, for example, epoxy groups, aldehydes and ketones. Suitable reactive binder functional groups for reacting with the aldehydes and ketones include, for example, amines.

**[0071]** In some embodiments, the crosslinking agent is a cyclic acid anhydride, which effectively is at least bifunctional. Non-limiting examples of suitable cyclic acid anhydrides include, for example, 1,8-naphthalene dicarboxylic acid anhydride, itaconic anhydride, glutaric anhydride and citraconic anhydride, fumaric anhydride, phthalic anhydride, isophthalic anhydride, and terephthalic anhydride with maleic anhydride and phthalic anhydride being of particular interest.

**[0072]** The binder generally is capable of dispersing or dissolving the charge transport compound (in the case of the charge transport layer or a single layer construction) and/or the charge generating compound (in the case of the charge generating layer or a single layer construction). Examples of suitable binders for both the charge generating layer and charge transport layer generally include, for example, polystyrene-co-butadiene, polystyrene-co-acrylonitrile, modified

acrylic polymers, polyvinyl acetate, styrene-alkyd resins, soya-alkyl resins, polyvinylchloride, polyvinylidene chloride, polyacrylonitrile, polycarbonates, polyacrylic acid, polyacrylates, polymethacrylates, styrene polymers, polyvinyl butyral, alkyd resins, polyamides, polyurethanes, polyesters, polysulfones, polyethers, polyketones, phenoxy resins, epoxy resins, silicone resins, polysiloxanes, poly(hydroxyether) resins, polyhydroxystyrene resins, novolak, poly(phe-  
 5 nylglycidyl ether)-co-dicyclopentadiene, copolymers of monomers used in the above-mentioned polymers, and combinations thereof. In some embodiments, the binder comprises a polymer with a reactive hydrogen functionality, such as hydroxyl, thiol, an amino group, carboxyl group, or a combination thereof, that can react with the epoxy ring of the charge transport compounds of this invention or with a functional group of a crosslinking agent, such as a cyclic acid anhydride. In the organophotoreceptor, the functional group of the polymer can be bonded directly with the epoxy group  
 10 or indirectly through a co-reactive crosslinking agent, for example, a cyclic acid anhydride group, to form the corresponding and predictable reaction product. Suitable binders with reactive functionality include, for example, polyvinyl butyral, such as BX-1 and BX-5 from Sekisui Chemical Co. Ltd., Japan.

**[0073]** Suitable optional additives for any one or more of the layers include, for example, antioxidants, coupling agents, dispersing agents, curing agents, surfactants, and combinations thereof.

**[0074]** The photoconductive element overall typically has a thickness from about 10 microns to about 45 microns. In the dual layer embodiments having a separate charge generating layer and a separate charge transport layer, charge generation layer generally has a thickness from about 0.5 microns to about 2 microns, and the charge transport layer has a thickness from about 5 microns to about 35 microns. In embodiments in which the charge transport material and the charge generating compound are in the same layer, the layer with the charge generating compound and the charge  
 20 transport composition generally has a thickness from about 7 microns to about 30 microns. In embodiments with a distinct electron transport layer, the electron transport layer has an average thickness from about 0.5 microns to about 10 microns and in further embodiments from about 1 micron to about 3 microns. In general, an electron transport overcoat layer can increase mechanical abrasion resistance, increases resistance to carrier liquid and atmospheric moisture, and decreases degradation of the photoreceptor by corona gases. A person of ordinary skill in the art will  
 25 recognize that additional ranges of thickness within the explicit ranges above are contemplated and are within the present disclosure.

**[0075]** Generally, for the organophotoreceptors described herein, the charge generation compound is in an amount from about 0.5 to about 25 weight percent, in further embodiments in an amount from about 1 to about 15 weight percent, and in other embodiments in an amount from about 2 to about 10 weight percent, based on the weight of the photoconductive layer. Suitably, the charge transport material is in an amount from about 10 to about 80 weight percent,  
 30 based on the weight of the photoconductive layer, in further embodiments in an amount from about 35 to about 60 weight percent, and in other embodiments from about 45 to about 55 weight percent, based on the weight of the photoconductive layer. The optional second charge transport material, when present, can be in an amount of at least about 2 weight percent, in other embodiments from about 2.5 to about 25 weight percent, based on the weight of the photoconductive layer, and in further embodiments in an amount from about 4 to about 20 weight percent, based on the weight of the photoconductive layer. Suitably, the binder is in an amount from about 15 to about 80 weight percent,  
 35 based on the weight of the photoconductive layer, and in further embodiments in an amount from about 20 to about 75 weight percent, based on the weight of the photoconductive layer. A person of ordinary skill in the art will recognize that additional ranges within the explicit ranges of compositions are contemplated and are within the present disclosure.

**[0076]** For the dual layer embodiments with a separate charge generating layer and a charge transport layer, the charge generation layer generally comprises a binder in an amount from about 10 to about 90 weight percent, in further  
 40 embodiments from about 15 to about 80 weight percent and in some embodiments in an amount from about 20 to about 75 weight percent, based on the weight of the charge generation layer. The optional charge transport material in the charge generating layer, if present, generally can be in an amount of at least about 2.5 weight percent, in further  
 45 embodiments from about 4 to about 30 weight percent and in other embodiments in an amount from about 10 to about 25 weight percent, based on the weight of the charge generating layer. The charge transport layer generally comprises a binder in an amount from about 20 weight percent to about 70 weight percent and in further embodiments in an amount from about 30 weight percent to about 50 weight percent. A person of ordinary skill in the art will recognize that additional ranges of binder concentrations for the dual layer embodiments within the explicit ranges above are  
 50 contemplated and are within the present disclosure.

**[0077]** For the embodiments with a single layer having a charge generating compound and a charge transport material, the photoconductive layer generally comprises a binder, a charge transport material, and a charge generation compound. The charge generation compound can be in an amount from about 0.05 to about 25 weight percent and in  
 55 further embodiment in an amount from about 2 to about 15 weight percent, based on the weight of the photoconductive layer. The charge transport material can be in an amount from about 10 to about 80 weight percent, in other embodiments from about 25 to about 65 weight percent, in additional embodiments from about 30 to about 60 weight percent and in further embodiments in an amount from about 35 to about 55 weight percent, based on the weight of the photoconductive layer, with the remainder of the photoconductive layer comprising the binder, and optional additives, such

as any conventional additives. A single layer with a charge transport composition and a charge generating compound generally comprises a binder in an amount from about 10 weight percent to about 75 weight percent, in other embodiments from about 20 weight percent to about 60 weight percent, and in further embodiments from about 25 weight percent to about 50 weight percent. Optionally, the layer with the charge generating compound and the charge transport material may comprise a second charge transport material. The optional second charge transport material, if present, generally can be in an amount of at least about 2.5 weight percent, in further embodiments from about 4 to about 30 weight percent and in other embodiments in an amount from about 10 to about 25 weight percent, based on the weight of the photoconductive layer. A person of ordinary skill in the art will recognize that additional composition ranges within the explicit compositions ranges for the layers above are contemplated and are within the present disclosure.

**[0078]** In general, any layer with an electron transport compound can advantageously further include a UV light stabilizer. In particular, the electron transport layer generally can comprise an electron transport compound, a binder, and an optional UV light stabilizer. An overcoat layer comprising an electron transport compound is described further in copending U.S. Patent Application Serial No. 10/396,536 to Zhu et al. entitled, "Organophotoreceptor With An Electron Transport Layer," published as US 2003/0194626 A1, incorporated herein by reference. For example, an electron transport compound as described above may be used in the release layer of the photoconductors described herein. The electron transport compound in an electron transport layer can be in an amount from about 10 to about 50 weight percent, and in other embodiments in an amount from about 20 to about 40 weight percent, based on the weight of the electron transport layer. A person of ordinary skill in the art will recognize that additional ranges of compositions within the explicit ranges are contemplated and are within the present disclosure.

**[0079]** The UV light stabilizer, if present, in any one or more appropriate layers of the photoconductor generally is in an amount from about 0.5 to about 25 weight percent and in some embodiments in an amount from about 1 to about 10 weight percent, based on the weight of the particular layer. A person of ordinary skill in the art will recognize that additional ranges of compositions within the explicit ranges are contemplated and are within the present disclosure.

**[0080]** For example, the photoconductive layer may be formed by dispersing or dissolving the components, such as one or more of a charge generating compound, the charge transport material of this invention, a second charge transport material such as a charge transport compound or an electron transport compound, a UV light stabilizer, and a polymeric binder in organic solvent, coating the dispersion and/or solution on the respective underlying layer and drying the coating. In particular, the components can be dispersed by high shear homogenization, ball-milling, attritor milling, high energy bead (sand) milling or other size reduction processes or mixing means known in the art for effecting particle size reduction in forming a dispersion.

**[0081]** The photoreceptor may optionally have one or more additional layers as well. An additional layer can be, for example, a sub-layer or an overcoat layer, such as a barrier layer, a release layer, a protective layer, or an adhesive layer. A release layer or a protective layer may form the uppermost layer of the photoconductor element. A barrier layer may be sandwiched between the release layer and the photoconductive element or used to overcoat the photoconductive element. The barrier layer provides protection from abrasion to the underlayers. An adhesive layer locates and improves the adhesion between a photoconductive element, a barrier layer and a release layer, or any combination thereof. A sub-layer is a charge blocking layer and locates between the electrically conductive substrate and the photoconductive element. The sub-layer may also improve the adhesion between the electrically conductive substrate and the photoconductive element.

**[0082]** Suitable barrier layers include, for example, coatings such as crosslinkable siloxanol-colloidal silica coating and hydroxylated silsesquioxane-colloidal silica coating, and organic binders such as polyvinyl alcohol, methyl vinyl ether/maleic anhydride copolymer, casein, polyvinyl pyrrolidone, polyacrylic acid, gelatin, starch, polyurethanes, polyimides, polyesters, polyamides, polyvinyl acetate, polyvinyl chloride, polyvinylidene chloride, polycarbonates, polyvinyl butyral, polyvinyl acetoacetal, polyvinyl formal, polyacrylonitrile, polymethyl methacrylate, polyacrylates, polyvinyl carbazoles, copolymers of monomers used in the above-mentioned polymers, vinyl chloride/vinyl acetate/vinyl alcohol terpolymers, vinyl chloride/vinyl acetate/maleic acid terpolymers, ethylene/vinyl acetate copolymers, vinyl chloride/vinylidene chloride copolymers, cellulose polymers, and mixtures thereof. The above barrier layer polymers optionally may contain small inorganic particles such as fumed silica, silica, titania, alumina, zirconia, or a combination thereof. Barrier layers are described further in U.S. Patent 6,001,522 to Woo et al., entitled "Barrier Layer For Photoconductor Elements Comprising An Organic Polymer And Silica," incorporated herein by reference. The release layer topcoat may comprise any release layer composition known in the art. In some embodiments, the release layer is a fluorinated polymer, siloxane polymer, fluorosilicone polymer, silane, polyethylene, polypropylene, polyacrylate, or a combination thereof. The release layers can comprise crosslinked polymers.

**[0083]** The release layer may comprise, for example, any release layer composition known in the art. In some embodiments, the release layer comprises a fluorinated polymer, siloxane polymer, fluorosilicone polymer, polysilane, polyethylene, polypropylene, polyacrylate, poly(methyl methacrylate-co-methacrylic acid), urethane resins, urethane-epoxy resins, acrylated-urethane resins, urethane-acrylic resins, or a combination thereof. In further embodiments, the release layers comprise crosslinked polymers.

[0084] The protective layer can protect the organophotoreceptor from chemical and mechanical degradation. The protective layer may comprise any protective layer composition known in the art. In some embodiments, the protective layer is a fluorinated polymer, siloxane polymer, fluorosilicone polymer, polysilane, polyethylene, polypropylene, polyacrylate, poly(methyl methacrylate-co-methacrylic acid), urethane resins, urethane-epoxy resins, acrylated-urethane resins, urethane-acrylic resins, or a combination thereof. In some embodiments of particular interest, the release layers are crosslinked polymers.

[0085] An overcoat layer may comprise an electron transport compound as described further in copending U.S. Patent Application Serial No. 10/396,536, filed on March 25, 2003 to Zhu et al. entitled, "Organoreceptor With An Electron Transport Layer," published as US 2003/0194626 A1, incorporated herein by reference. For example, an electron transport compound, as described above, may be used in the release layer of this invention. The electron transport compound in the overcoat layer can be in an amount from about 2 to about 50 weight percent, and in other embodiments in an amount from about 10 to about 40 weight percent, based on the weight of the release layer. A person of ordinary skill in the art will recognize that additional ranges of composition within the explicit ranges are contemplated and are within the present disclosure.

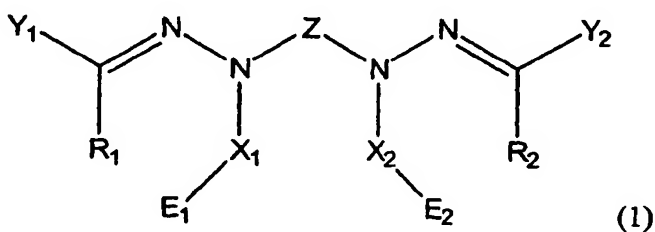
[0086] Generally, adhesive layers comprise a film forming polymer, such as polyester, polyvinylbutyral, polyvinylpyrrolidone, polyurethane, polymethyl methacrylate, poly(hydroxy amino ether) and the like. Barrier and adhesive layers are described further in U.S. Patent 6,180,305 to Ackley et al., entitled "Organic Photoreceptors for Liquid Electrophotography," incorporated herein by reference.

[0087] Sub-layers can comprise, for example, polyvinylbutyral, organosilanes, hydrolyzable silanes, epoxy resins, polyesters, polyamides, polyurethanes, and the like. In some embodiments, the sub-layer has a dry thickness between about 20 Angstroms and about 2,000 Angstroms. Sublayers containing metal oxide conductive particles can be between about 1 and about 25 microns thick. A person of ordinary skill in the art will recognize that additional ranges of compositions and thickness within the explicit ranges are contemplated and are within the present disclosure.

[0088] The charge transport materials as described herein, and photoreceptors including these compounds, are suitable for use in an imaging process with either dry or liquid toner development. For example, any dry toners and liquid toners known in the art may be used in the process and the apparatus of this invention. Liquid toner development can be desirable because it offers the advantages of providing higher resolution images and requiring lower energy for image fixing compared to dry toners. Examples of suitable liquid toners are known in the art. Liquid toners generally comprise toner particles dispersed in a carrier liquid. The toner particles can comprise a colorant/pigment, a resin binder, and/or a charge director. In some embodiments of liquid toner, a resin to pigment ratio can be from 1:1 to 10:1, and in other embodiments, from 4:1 to 8:1. Liquid toners are described further in Published U.S. Patent Applications 2002/0128349, entitled "Liquid Inks Comprising A Stable Organosol," 2002/0086916, entitled "Liquid Inks Comprising Treated Colorant Particles," and 2002/0197552, entitled "Phase Change Developer For Liquid Electrophotography," all three of which are incorporated herein by reference.

#### Charge Transport Material

[0089] As described herein, an organophotoreceptor comprises a charge transport material having the formula



where  $Y_1$  and  $Y_2$  are, each independently, an arylamine group;

$R_1$  and  $R_2$  comprise, each independently, H, an alkyl group, an alkenyl group, a heterocyclic group, or an aromatic group;

$X_1$  and  $X_2$ , each independently, are bridging groups, such as groups having the formula  $-(CH_2)_m-$ , branched or linear, where  $m$  is an integer between 0 and 20, inclusive, and one or more of the methylene groups is optionally replaced by O, S, C=O, O=S=O, a heterocyclic group, an aromatic group, urethane, urea, an ester group, an  $NR_3$  group, a  $CHR_4$  group, or a  $CR_5R_6$  group where  $R_3$ ,  $R_4$ ,  $R_5$ , and  $R_6$  comprise, each independently, H, hydroxyl group, thiol group, an alkyl group, an alkenyl group, a heterocyclic group, or an aromatic group;

$E_1$  and  $E_2$  are, each independently, an epoxy group; and

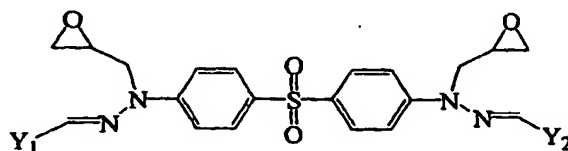
Z is a linking group comprising an alkyl group, an alkenyl group, a heterocyclic group, or an aromatic group.

[0090] Preferably, Z comprises an aromatic group.

[0091] Preferably,  $Y_1$  and  $Y_2$  are, each independently, a carbazolyl group, an (N,N-disubstituted)arylamine group, or a julolidinyl group.

[0092] Preferably,  $E_1$  and  $E_2$  are, each independently, an oxiranyl ring.

[0093] Preferably, the charge transport material is selected from the group of compounds represented by the following formula:



where  $Y_1$  and  $Y_2$  are, each independently, an arylamine group.

[0094] Preferably, the photoconductive element of the organophotoreceptor further comprises a second charge transport material.

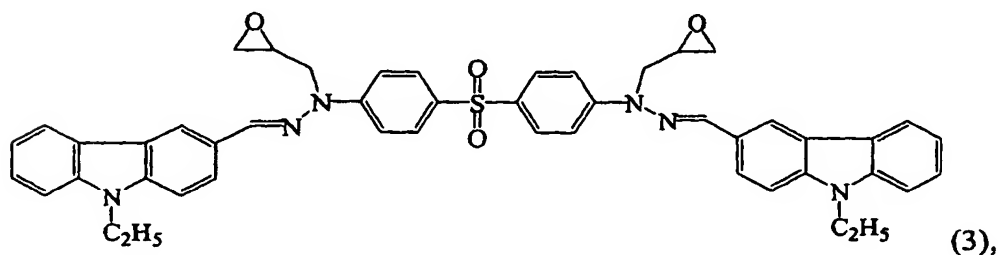
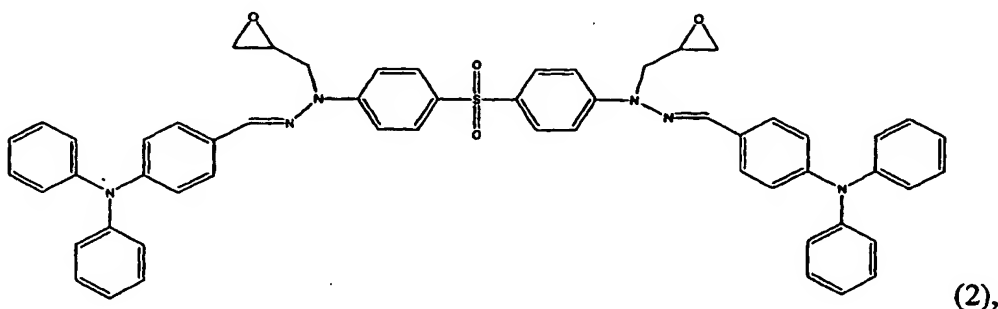
[0095] Preferably, the second charge transport material comprises an electron transport compound.

[0096] Preferably, the photoconductive element of the organophotoreceptor further comprises a binder.

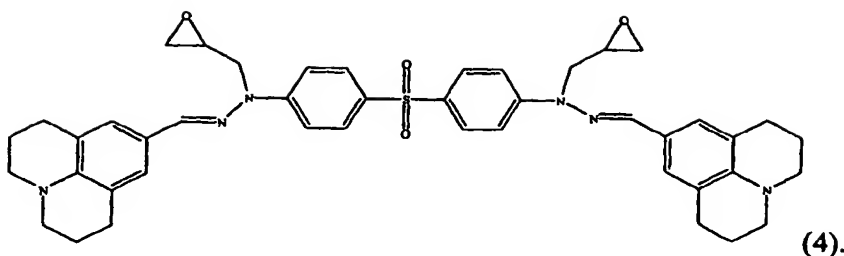
[0097] In some embodiments, Z comprises an aromatic group. In further embodiments  $R_1$  and  $R_2$  are both H.

[0098] In some embodiments,  $X_1$  and  $X_2$  each independently, are bridging groups, such as groups having the formula  $-(CH_2)_m-$ , branched or linear, where m is an integer between 0 and 12, inclusive, especially between 0 and 6, inclusive, notably 1, and one or more of the methylene groups is optionally replaced by O, S, C=O, O=S=O, a heterocyclic group, an aromatic group, urethane, urea, an ester group, an  $NR_3$  group, a  $CHR_4$  group, or a  $CR_5R_6$  group where  $R_3$ ,  $R_4$ ,  $R_5$ , and  $R_6$  comprise, each independently, H, hydroxyl group, thiol group, an alkyl group, an alkenyl group, a heterocyclic group, or an aromatic group.

[0099] Specific, non-limiting examples of suitable charge transport materials within the general Formula (1) of the present invention have the following structures (2)-(4):



and



### Synthesis Of Charge Transport Materials

**[0100]** The synthesis of the charge transport materials of this invention can be prepared by the following multi-step synthetic procedure, although other suitable procedures can be used by a person of ordinary skill in the art based on the disclosure herein.

**[0101]** The first step is a nucleophilic substitution reaction between a linking organic compound having two halogen groups (i.e. dibromoalkanes or 4,4'-dichlorodiphenyl sulfone) and hydrazine hydrate. The linking organic compound may or may not be symmetric with respect to the two halogen groups. The reaction mixture may be refluxed for 24 hours. The product of the nucleophilic substitution is the corresponding aromatic compound having two hydrazine groups, such as 4,4'-dihydrazinodiphenyl sulfone. In the second step, the aromatic compound having two hydrazine groups may react with an arylamine having an aldehyde or a keto group to form the corresponding aromatic compound having two hydrazone groups. If desired, two different arylamine compounds can be reacted with the di-hydrazine compound. The use of one or two arylamine reactants with keto groups result in a charge transport material with R<sub>1</sub> and/or R<sub>2</sub> groups that differ from H. While the use of two different arylamine compounds may result in a mixture of products, a person of ordinary skill in the art can reduce the synthesis of undesired forms of product through either sequential or simultaneous reactions, and the different product compounds can be separated from each other through appropriate purification approaches.

**[0102]** In the third step, the two NH groups of the aromatic compound having two hydrazone groups may react with an organic halide comprising an epoxy group in the presence of an alkaline to form a charge transport material having two epoxidated-hydrazone groups bonded together through a linking group. Non-limiting examples of suitable organic halide comprising an epoxy group for this invention are epichlorohydrins, such as epichlorohydrin. The organic halide comprising an epoxy group may also be prepared by the epoxidation reaction of the corresponding organic halide having an olefin group. The epoxidation reaction is described in Carey et al., "Advanced Organic Chemistry, Part B: Reactions and Synthesis," New York, 1983, pp. 494-498, incorporated herein by reference. The organic halide having an olefin group may be prepared by the Wittig reaction between a suitable organic halide having an aldehyde or keto group and a suitable Wittig reagent. The Wittig and related reactions are described in Carey et al., "Advanced Organic Chemistry, Part B: Reactions and Synthesis," New York, 1983, pp. 69-77, incorporated herein by reference.

**[0103]** Depending on the particular reactivities of the groups, the order of some of the reactions may be changed.

**[0104]** As noted above, the epoxy groups can be reacted with functional groups of a polymer binder directly or through a crosslinking agent. The reactions of epoxy groups with appropriate functional groups are described further in C.A. May, editor, "Epoxy Resins Chemistry And Technology," (Marcel Dekker, New York, 1988) and in B. Ellis, editor, "Chemistry And Technology Of Epoxy Resins," (Blackie Academic And Professional, London, 1993), both of which are incorporated herein by reference.

**[0105]** In general, the charge transport material is combined with the binder and any other components of the particular layer of the organophotoreceptor for forming the particular layer. If a crosslinking agent is used, it may be desirable to react the crosslinking agent first with either the charge transport material or with the polymer binder before combining the other ingredients. A person of ordinary skill in the art can evaluate the appropriate reaction order, such as combining all of the components at one time or sequentially, for forming the layer with desired properties.

**[0106]** The invention will now be described further by way of the following illustrative examples. These examples are to be viewed as being illustrative of specific materials falling within the broader disclosure presented above.

### EXAMPLES

#### Example 1 - Synthesis And Characterization Charge Transport Materials

**[0107]** This example described the synthesis and characterization of Compound (2) in which the numbers refer to



formula numbers above. The characterization involves the chemical characterization, and the electronic characterization of materials formed with the compound is described in the subsequent examples.

#### Compound (2)

**[0108]** A suspension of 4,4'-dichlorodiphenyl sulfone (20 g, 0.069 mol, obtained from Aldrich) in hydrazine hydrate (158 ml, obtained from Aldrich) was refluxed for 24 hours. The mixture was cooled to room temperature and crystals precipitated out. The crystals were filtered off and washed 3 times with water and one time with isopropanol. The yield of the product, 4,4'-dihydrazinodiphenyl sulfone, was 15.75 g (81.8%). The product had a melting point of 193-194 °C. The literature procedure for the preparation of 4,4'-dihydrazinodiphenyl sulfone was published in *Khimiya Geterotsiklicheskikh Soedinenii*, 11, p.1508-1510, 1980 (issued in the Republic of Latvia). The article is incorporated herein by reference.

**[0109]** A mixture of 4-(diphenylamino)benzaldehyde (25 g, 0.09 mol, obtained from Aldrich), 4,4'-dihydrazinodiphenyl sulfone (11.37 g, 0.041 mol) and 80 ml of dioxane was added to a 250 ml round bottom flask equipped with a reflux condenser and a magnetic stirrer. The reaction mixture was heated at 50 °C for 2 hours with stirring. The solvent was removed by evaporation to form 4,4'-dihydrazondiphenyl sulfone triphenylaminohydrazone. The yield was 30.1 g (93.4%).

**[0110]** A mixture of 4,4'-dihydrazondiphenyl sulfone triphenylaminohydrazone (30.1 g, 0.038 mol) and epichlorohydrin (68 ml, 0.855 mol, obtained from Aldrich) was added to a 250 ml 3-neck round bottom flask equipped with a reflux condenser, a thermometer and a magnetic stirrer. The reaction mixture was stirred vigorously at 35-40 °C for 7 hours. During this time, powdered 85 % potassium hydroxide (KOH, 11.3 g, 0.171 mol) and anhydrous sodium sulfate ( $\text{Na}_2\text{SO}_4$ , 9 g, 0.0228 mol) were added in three portions with prior cooling of the reaction mixture to 20-25 °C. After the termination of the reaction, the mixture was cooled to room temperature and filtered. The organic part was treated with ethyl acetate and washed with distilled water until the washed water became neutral. The organic layer was dried over anhydrous magnesium sulfate, treated with activated charcoal, and filtered. The solvents were evaporated to form Compound (2). Compound (2) was purified by column chromatography (silica gel, grade 62, 60-200 mesh, 150 A, Aldrich) using a mixture of acetone and hexane in a ratio of 1:4 by volume as the eluant. The fractions containing Compound (2) were collected, and the solvents were evaporated. Compound (2) was recrystallized from a mixture of acetone and hexane in a ratio of 1:4 by volume and dried at 50 °C in a vacuum oven for 6 hours. The yield of Compound (2) was 19.3 g (56 %). Compound (2) had a melting point of 223-225 °C. The  $^1\text{H}$  NMR spectrum (100 MHz) of Compound (2) in  $\text{CDCl}_3$  was characterized by the following chemical shifts ( $\delta$ , ppm): 8.0-6.8 (m, 38H,  $\text{CH}=\text{N}$ , Ar); 4.5-4.3 (dd, 2H, one proton of  $\text{NCH}_2$ ); 4.1-3.8 (dd, 2H, another proton of  $\text{NCH}_2$ ); 3.2 (m, 2H, CH); 2.9-2.8 (dd, 2H, one proton of  $\text{OCH}_2$ ); 2.7-2.5 (dd, another proton of  $\text{OCH}_2$ ). An elemental analysis yielded the following results in weight percent: C 74.71; H 5.33; N 9.45, which compared with calculated values for  $\text{C}_{38}\text{H}_{35}\text{N}_5\text{O}_2$ , in weight percent of: C 74.64; H 5.37; N 9.33.

#### Compound (3)

**[0111]** Compound (3) may be prepared according to the procedure for Compound (2) except that 4-(diphenylamino)benzaldehyde is replaced with 9-ethyl-3-carbazole carboxaldehyde (commercially available from Aldrich, Milwaukee, WI).

#### Compound (4)

**[0112]** Compound (4) may be prepared according to the procedure for Compound (2) except that 4-(diphenylamino)benzaldehyde is replaced with julolidine aldehyde, which may be prepared according to the following procedure. Julolidine (100 g, 0.6 moles, obtained from Aldrich Chemicals Co, Milwaukee, WI) was dissolved in DMF (200 ml, obtained from Aldrich) in a 500 ml three neck round bottom flask. The flask was cooled to 0 °C in an ice bath. Phosphorus oxychloride ( $\text{POCl}_3$ , 107 g, 0.7 mole, Aldrich) was added dropwise while the temperature was kept below 5 °C. After the addition of  $\text{POCl}_3$  was completed, the flask was placed in a steam bath and stirred for a period of 1 hour. The flask was cooled to room temperature, and the solution was added slowly to a large excess of distilled water with a vigorous stirring. The stirring was continued for 2 hours. The solid that formed was filtered off and washed repeatedly with water until the washed water became neutral. The product, julolidine aldehyde, was dried in a vacuum oven at 50 °C for 4 hours.

#### Example 2 - Charge Mobility Measurements

**[0113]** This example describes the measurement of charge mobility for charge transport materials, such as Compound (2) described above.



Sample 1

[0114] A mixture of 0.1 g of Compound (2) and 0.1 g of polycarbonate Z-200 (from Mitsubishi Gas Chemical) was dissolved in 2 ml of tetrahydrofuran. The solution was coated on a polyester film with conductive aluminum layer with a dip roller. After the coating was dried for 1 hour at 80 °C, a clear 10 µm thick layer was formed. The hole mobility of the sample was measured. The results are presented in Table 1.

Mobility Measurements

[0115] Each sample was corona charged positively up to a surface potential U and illuminated with 2 ns long nitrogen laser light pulse. The hole mobility  $\mu$  was determined as described in Kalade et al., "Investigation of charge carrier transfer in electrophotographic layers of chalcogenide glasses," Proceeding IPCS 1994: The Physics and Chemistry of Imaging Systems, Rochester, NY, pp. 747-752, incorporated herein by reference. The hole mobility measurement was repeated with changes to the charging regime to charge the sample to different U values, which corresponded to different electric field strength, E, inside the layer. This dependence on electric field strength was approximated by the formula

$$\mu = \mu_0 e^{\alpha \sqrt{E}}$$

Here E is electric field strength,  $\mu_0$  is the zero field mobility and  $\alpha$  is Pool-Frenkel parameter. Table 1 lists the mobility characterizing parameters  $\mu_0$  and  $\alpha$  values and the mobility value at the  $6.4 \times 10^5$  V/cm field strength as determined from these measurements.

Table 1

Sample	$\mu_0$ (cm <sup>2</sup> N/V·s)	$\mu$ (cm <sup>2</sup> /V·s) at $6.4 \cdot 10^5$ V/cm	$\alpha$ (cm/V) <sup>0.5</sup>	Ionization Potential (eV)
1 [Compound (2)]	$5 \cdot 10^{-9}$	$1.1 \cdot 10^{-6}$	0.0068	5.47

Example 3 - Ionization Potential Measurements

[0116] This example describes the measurement of the ionization potential for the charge transport materials, such as Compound (2) described in Example 1.

[0117] To perform the ionization potential measurements, a thin layer of charge transport material about 0.5 µm thickness was coated from a solution of 2 mg of charge transport material in 0.2 ml of tetrahydrofuran on a 20 cm<sup>2</sup> substrate surface. The substrate was polyester film with an aluminum layer over a methylcellulose sublayer of about 0.4 µm thickness.

[0118] Ionization potential was measured as described in Grigalevicius et al., "3,6-Di(N-diphenylamino)-9-phenyl-carbazole and its methyl-substituted derivative as novel hole-transporting amorphous molecular materials," Synthetic Metals 128 (2002), p. 127-131, incorporated herein by reference. In particular, each sample was illuminated with monochromatic light from the quartz monochromator with a deuterium lamp source. The power of the incident light beam was  $2.5 \cdot 10^{-8}$  W. A negative voltage of -300 V was supplied to the sample substrate. A counter-electrode with the  $4.5 \times 15$  mm<sup>2</sup> slit for illumination was placed at 8 mm distance from the sample surface. The counter-electrode was connected to the input of a BK2-16 type electrometer, working in the open input regime, for the photocurrent measurement. A  $10^{-15}$  -  $10^{-12}$  amp photocurrent was flowing in the circuit under illumination. The photocurrent, I, was strongly dependent on the incident light photon energy hv. The  $I^{0.5} = f(hv)$  dependence was plotted. Usually, the dependence of the square root of photocurrent on incident light quanta energy is well described by linear relationship near the threshold (see references "Ionization Potential of Organic Pigment Film by Atmospheric Photoelectron Emission Analysis," *Electrophotography*, 28, Nr. 4, p. 364 (1989) by E. Miyamoto, Y. Yamaguchi, and M. Yokoyama; and "Photoemission in Solids," Topics in Applied Physics, 26, 1-103 (1978) by M. Cordona and L. Ley, both of which are incorporated herein by reference). The linear part of this dependence was extrapolated to the hv axis, and the Ip value was determined as the photon energy at the interception point. The ionization potential measurement has an error of  $\pm 0.03$  eV. Table 1 lists the ionization potential value of Compound (2).

[0119] As understood by those skilled in the art, additional substitution, variation among substituents, and alternative methods of synthesis and use may be practiced within the scope and intent of the present disclosure of the invention. The embodiments above are intended to be illustrative and not limiting. Additional embodiments are within the claims.

Although the present invention has been described with reference to particular embodiments, workers skilled in the art will recognize that changes may be made in form and detail without departing from the spirit and scope of the invention.

[0120] Although a few preferred embodiments have been shown and described, it will be appreciated by those skilled in the art that various changes and modifications might be made without departing from the scope of the invention, as defined in the appended claims.

[0121] Attention is directed to all papers and documents which are filed concurrently with or previous to this specification in connection with this application and which are open to public inspection with this specification, and the contents of all such papers and documents are incorporated herein by reference.

[0122] All of the features disclosed in this specification (including any accompanying claims, abstract and drawings), and/or all of the steps of any method or process so disclosed, may be combined in any combination, except combinations where at least some of such features and/or steps are mutually exclusive.

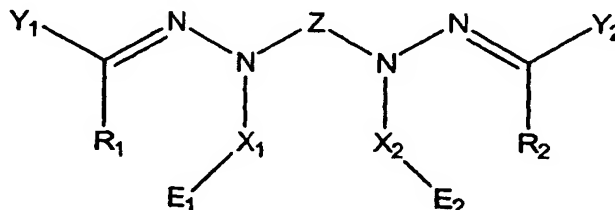
[0123] Each feature disclosed in this specification (including any accompanying claims, abstract and drawings) may be replaced by alternative features serving the same, equivalent or similar purpose, unless expressly stated otherwise. Thus, unless expressly stated otherwise, each feature disclosed is one example only of a generic series of equivalent or similar features.

[0124] The invention is not restricted to the details of the foregoing embodiment(s). The invention extends to any novel one, or any novel combination, of the features disclosed in this specification (including any accompanying claims, abstract and drawings), or to any novel one, or any novel combination, of the steps of any method or process so disclosed.

## Claims

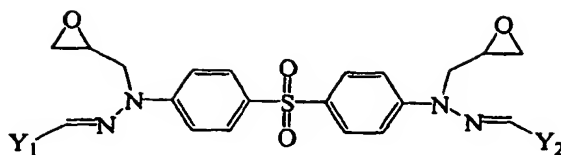
1. An organophotoreceptor comprising an electrically conductive substrate and a photoconductive element on the electrically conductive substrate, the photoconductive element comprising:

(a) a charge transport material having the formula



where  $Y_1$  and  $Y_2$  are, each independently, an arylamine group;  
 $R_1$  and  $R_2$  comprise, each independently, H, an alkyl group, an alkenyl group, a heterocyclic group, or an aromatic group;  
 $X_1$  and  $X_2$ , each independently, are bridging groups;  
 $E_1$  and  $E_2$  are, each independently, an epoxy group; and  
 $Z$  is a linking group comprising an alkyl group, an alkenyl group, a heterocyclic group, or an aromatic group; and  
 (b) a charge generating compound.

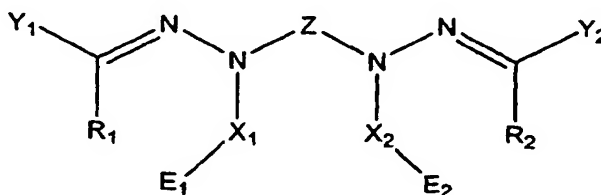
2. An organophotoreceptor according to claim 1 wherein  $Z$  comprises an aromatic group.
3. An organophotoreceptor according to either of claims 1 and 2 wherein  $Y_1$  and  $Y_2$  are, each independently, a carbazolyl group, an (N,N-disubstituted)arylamine group, or a julolidinyl group.
4. An organophotoreceptor according to any preceding claim wherein  $E_1$  and  $E_2$  are, each independently, an oxiranyl ring.
5. An organophotoreceptor according to claim 1 wherein the charge transport material is selected from the group of compounds represented by the following formula:



where  $Y_1$  and  $Y_2$  are, each independently, an arylamine group.

6. An organophotoreceptor according to any of claims 1 to 4 wherein  $X_1$  and  $X_2$ , each independently, have the formula  $-(CH_2)_m-$ , branched or linear, where  $m$  is an integer between 0 and 20, inclusive, and one or more of the methylene groups is optionally replaced by O, S, C=O, O=S=O, a heterocyclic group, an aromatic group, urethane, urea, an ester group, an  $NR_3$  group, a  $CHR_4$  group, or a  $CR_5R_6$  group where  $R_3$ ,  $R_4$ ,  $R_5$ , and  $R_6$  comprise, each independently, H, hydroxyl group, thiol group, an alkyl group, an alkenyl group, a heterocyclic group, or an aromatic group.
7. An organophotoreceptor according to any preceding claim wherein the photoconductive element further comprises a second charge transport material.
8. An organophotoreceptor according to claim 7 wherein the second charge transport material comprises an electron transport compound.
9. An organophotoreceptor according to any preceding claim wherein the photoconductive element further comprises a binder.
10. An electrophotographic imaging apparatus comprising:
  - (a) a light imaging component; and
  - (b) an organophotoreceptor oriented to receive light from the light imaging component, the organophotoreceptor comprising an electrically conductive substrate and a photoconductive element on the electrically conductive substrate, the photoconductive element comprising:

(i) a charge transport material having the formula

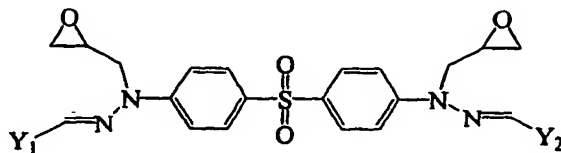


where  $Y_1$  and  $Y_2$  are, each independently, an arylamine group;  
 $R_1$  and  $R_2$  comprise, each independently, H, an alkyl group, an alkenyl group, a heterocyclic group, or an aromatic group;  
 $X_1$  and  $X_2$ , each independently, are bridging groups;  
 $E_1$  and  $E_2$  are, each independently, an epoxy group; and  
 $Z$  is a linking group comprising an alkyl group, an alkenyl group, a heterocyclic group, or an aromatic group; and  
 (ii) a charge generating compound.

11. An electrophotographic imaging apparatus according to claim 10 wherein  $Z$  comprises an aromatic group.
12. An electrophotographic imaging apparatus according to either of claims 10 and 11 wherein  $Y_1$  and  $Y_2$  are, each independently, a carbazolyl group, an (N,N-disubstituted)arylamine group, or a julolidinyl group.
13. An electrophotographic imaging apparatus according to any of claims 10 to 12 wherein  $E_1$  and  $E_2$  are, each inde-

pendently, an oxiranyl ring.

14. An electrophotographic imaging apparatus according to claim 10 wherein the charge transport material is selected from the group of compounds represented by the following formula:

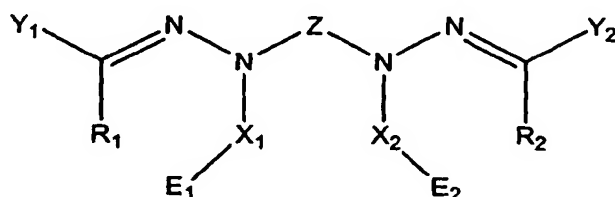


where  $Y_1$  and  $Y_2$  are, each independently, an arylamine group.

15. An electrophotographic imaging apparatus according to any of claims 10 to 13 wherein  $X_1$  and  $X_2$ , each independently, have the formula  $-(CH_2)_m-$ , branched or linear, where  $m$  is an integer between 0 and 20, inclusive, and one or more of the methylene groups is optionally replaced by O, S, C=O, O=S=O, a heterocyclic group, an aromatic group, urethane, urea, an ester group, an  $NR_3$  group, a  $CHR_4$  group, or a  $CR_5R_6$  group where  $R_3$ ,  $R_4$ ,  $R_5$ , and  $R_6$  comprise, each independently, H, hydroxyl group, thiol group, an alkyl group, an alkenyl group, a heterocyclic group, or an aromatic group.
16. An electrophotographic imaging apparatus according to any of claims 10 to 15 wherein the photoconductive element further comprises a second charge transport material.
17. An electrophotographic imaging apparatus according to claim 16 wherein second charge transport material comprises an electron transport compound.
18. An electrophotographic imaging apparatus according to any of claims 10 to 17 further comprising a liquid toner dispenser.
19. An electrophotographic imaging process comprising;

(a) applying an electrical charge to a surface of an organophotoreceptor comprising an electrically conductive substrate and a photoconductive element on the electrically conductive substrate, the photoconductive element comprising

(i) a charge transport material having the formula

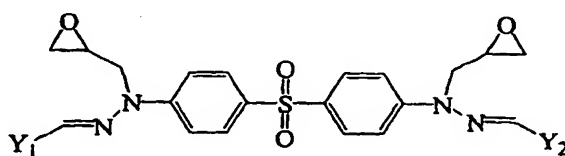


where  $Y_1$  and  $Y_2$  are, each independently, an arylamine group;  
 $R_1$  and  $R_2$  comprise, each independently, H, an alkyl group, an alkenyl group, a heterocyclic group, or an aromatic group;  
 $X_1$  and  $X_2$ , each independently, are bridging groups;  
 $E_1$  and  $E_2$  are, each independently, an epoxy group; and  
 $Z$  is a linking group comprising an alkyl group, an alkenyl group, a heterocyclic group, or an aromatic group; and  
 (ii) a charge generating compound.

(b) imagewise exposing the surface of the organophotoreceptor to radiation to dissipate charge in selected

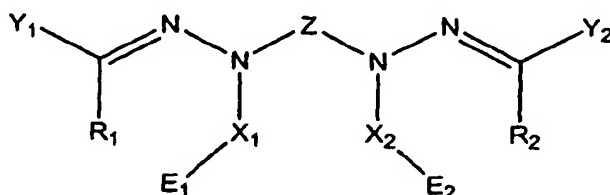
areas and thereby form a pattern of charged and uncharged areas on the surface;  
 (c) contacting the surface with a toner to create a toned image; and  
 (d) transferring the toned image to substrate.

20. An electrophotographic imaging process according to claim 19 wherein Z comprises an aromatic group.
21. An electrophotographic imaging process according to either of claims 19 and 20 wherein  $Y_1$  and  $Y_2$  are, each independently, a carbazolyl group, an (N,N-disubstituted)arylamine group, or a julolidinyl group.
22. An electrophotographic imaging process according to any of claims 19 to 21 wherein  $E_1$  and  $E_2$  are, each independently, an oxiranyl ring.
23. An electrophotographic imaging process according to claim 19 wherein the charge transport material is selected from the group of compounds represented by the following formula:



where  $Y_1$  and  $Y_2$  are, each independently, an arylamine group.

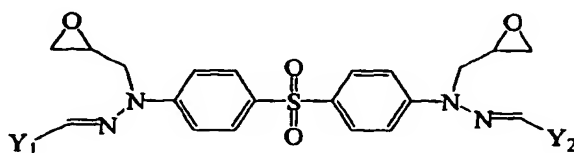
24. An electrophotographic imaging process according to any of claims 19 to 22 wherein  $X_1$  and  $X_2$ , each independently, have the formula  $-(CH_2)_m-$ , branched or linear, where m is an integer between 0 and 20, inclusive, and one or more of the methylene groups is optionally replaced by O, S, C=O, O=S=O, a heterocyclic group, an aromatic group, urethane, urea, an ester group, an  $NR_3$  group, a  $CHR_4$  group, or a  $CR_5R_6$  group where  $R_3$ ,  $R_4$ ,  $R_5$ , and  $R_6$  comprise, each independently, H, hydroxyl group, thiol group, an alkyl group, an alkenyl group, a heterocyclic group, or an aromatic group.
25. An electrophotographic imaging process according to any of claims 19 to 24 wherein the photoconductive element further comprises a second charge transport material.
26. An electrophotographic imaging process according to claim 25 wherein the second charge transport material comprises an electron transport compound.
27. An electrophotographic imaging process according to any of claims 19 to 26 wherein the photoconductive element further comprises a binder.
28. An electrophotographic imaging process according to any of claims 19 to 27 wherein the toner comprises a liquid toner comprising a dispersion of colorant particles in an organic liquid.
29. A charge transport material having the formula



where  $Y_1$  and  $Y_2$  are, each independently, an arylamine group;  
 $R_1$  and  $R_2$  comprise, each independently, H, an alkyl group, an alkenyl group, a heterocyclic group, or an aromatic group;

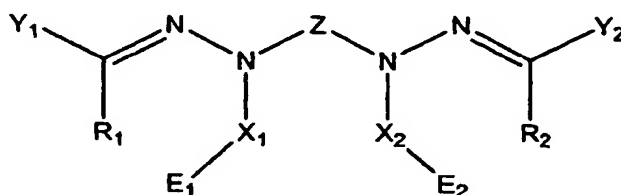
$X_1$  and  $X_2$ , each independently, are bridging groups;  
 $E_1$  and  $E_2$  are, each independently, an epoxy group; and  
 $Z$  is a linking group comprising an alkyl group, an alkenyl group, a heterocyclic group, or an aromatic group.

30. A charge transport material according to claim 29 wherein  $Z$  comprises an aromatic group.
31. A charge transport material according to either of claims 29 and 30 wherein  $Y_1$  and  $Y_2$  are, each independently, a carbazolyl group, an (N,N-disubstituted)arylamine group, or a julolidinyl group.
32. A charge transport material according to any of claims 29 to 31 wherein  $E_1$  and  $E_2$  are, each independently, an oxiranyl ring.
33. A charge transport material according to claim 29 wherein the charge transport material is selected from the group of compounds represented by the following formula:



where  $Y_1$  and  $Y_2$  are, each independently, an arylamine group.

34. A charge transport material according to any of claims 29 to 32 wherein  $X_1$  and  $X_2$ , each independently, have the formula  $-(CH_2)_m-$ , branched or linear, where  $m$  is an integer between 0 and 20, inclusive, and one or more of the methylene groups is optionally replaced by O, S, C=O, O=S=O, a heterocyclic group, an aromatic group, urethane, urea, an ester group, an  $NR_3$  group, a  $CHR_4$  group, or a  $CR_5R_6$  group where  $R_3$ ,  $R_4$ ,  $R_5$ , and  $R_6$  comprise, each independently, H, hydroxyl group, thiol group, an alkyl group, an alkenyl group, a heterocyclic group, or an aromatic group.
35. A polymeric charge transport material prepared by the reaction of a functional group in a polymeric binder with at least an epoxy group of a compound having the formula

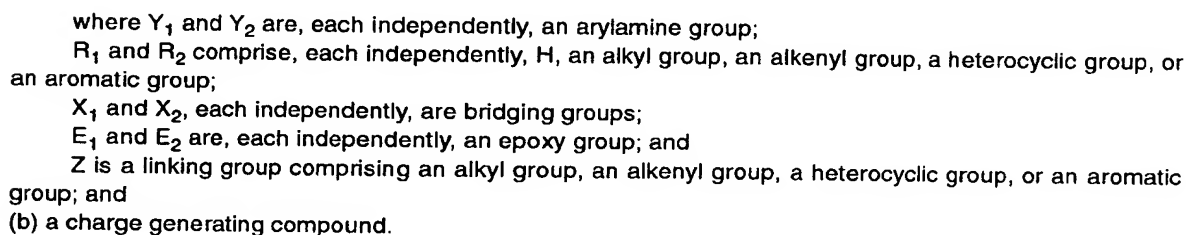


where  $Y_1$  and  $Y_2$  are, each independently, an arylamine group;  
 $R_1$  and  $R_2$  comprise, each independently, H, an alkyl group, an alkenyl group, a heterocyclic group, or an aromatic group;  
 $X_1$  and  $X_2$ , each independently, are bridging groups;  
 $E_1$  and  $E_2$  are, each independently, an epoxy group; and  
 $Z$  is a linking group comprising an alkyl group, an alkenyl group, a heterocyclic group, or an aromatic group.

36. A polymeric charge transport material according to claim 35 wherein the functional group of the binder is selected from the group consisting of hydroxyl group, carboxyl group, an amino group, and thiol group.
37. A polymeric charge transport material according to either of claims 35 and 36 wherein a crosslinking agent is bonded between the epoxy group and the functional group of the binder.
38. A polymeric charge transport material according to any of claims 35 to 37 wherein  $Z$  comprises an aromatic group.

40. A polymeric charge transport material according to any of claims 35 to 39 wherein  $X_1$  and  $X_2$ , each independently, have the formula  $-(CH_2)_m-$ , branched or linear, where  $m$  is an integer between 0 and 20, inclusive, and one or more of the methylene groups is optionally replaced by O, S, C=O, O=S=O, a heterocyclic group, an aromatic group, urethane, urea, an ester group, an  $NR_3$  group, a  $CHR_4$  group, or a  $CR_5R_6$  group where  $R_3$ ,  $R_4$ ,  $R_5$ , and  $R_6$  comprise, each independently, H, hydroxyl group, thiol group, an alkyl group, an alkenyl group, a heterocyclic group, or an aromatic group

- (a) a polymeric charge transport material prepared by the reaction of a functional group in a polymeric binder with at least an epoxy group of a compound having the formula



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European Patent  
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# EUROPEAN SEARCH REPORT

Application Number  
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DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
A	US 2003/232264 A1 (ZBIGNIEW TOKARSKI ET AL.) 18 December 2003 (2003-12-18)  * claims *	1-4, 7-13, 16-22, 25-32	G03G5/06 C07D303/06 C07D405/14
A	US 2003/232261 A1 (ZBIGNIEW TOKARSKI ET AL.) 18 December 2003 (2003-12-18)  * claims *	1-4, 7-13, 16-22, 25-32	
P,A	US 2004/081903 A1 (ZBIGNIEW TOKARSKI ET AL) 29 April 2004 (2004-04-29)  * claims *	1-4, 7-13, 16-22, 25-32	
P,A	US 2004/161685 A1 (VYTAUTAS GETAUTIS ET AL.) 19 August 2004 (2004-08-19)  * claims *	1-4, 7-13, 16-22, 25-32	TECHNICAL FIELDS SEARCHED (Int.Cl.7)  G03G C07D
The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 14 April 2005	Examiner Francois, J
<p>CATEGORY OF CITED DOCUMENTS</p> <p>X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document</p> <p>T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons &amp; : member of the same patent family, corresponding document</p>			

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EPO FORM 1503 (03.02) (P/4/001)



**ANNEX TO THE EUROPEAN SEARCH REPORT  
ON EUROPEAN PATENT APPLICATION NO.**

EP 04 25 7404

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.  
The members are as contained in the European Patent Office EDP file on  
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14-04-2005

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2003232264 A1	18-12-2003	KR 2003093132 A	06-12-2003
US 2003232261 A1	18-12-2003	KR 2003093131 A	06-12-2003
US 2004081903 A1	29-04-2004	US 2004161685 A1	19-08-2004
		CN 1532635 A	29-09-2004
		EP 1420303 A2	19-05-2004
		JP 2004143180 A	20-05-2004
US 2004161685 A1	19-08-2004	US 2004081903 A1	29-04-2004
		EP 1465020 A2	06-10-2004
		JP 2004302471 A	28-10-2004
		CN 1532635 A	29-09-2004
		EP 1420303 A2	19-05-2004
		JP 2004143180 A	20-05-2004

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82